Fermi National Accelerator Laboratory

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USE OF EPB DIPOLES AND R1 SEPTUM AS SPECTROMETER MAGNETS

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Introduction

The forward spectrometer used by E-177 to measure high transverse momentum p-p elastic scattering consists of one R1 septum magnet, two EPB dipoles and a series of MWPC's (see Figure 1). To maximize the acceptance of the experiment a region of field inside the magnets larger than the normal "good field" region was used. Accurate reconstruction of particle trajectories required that the fields be known for variations of the transverse coordinates inside the magnets of approximately $\pm$1/16 in.

Procedure

Existing measurements of these magnets are summarized in TM-434 and TM-450. They consist of values of the central field, B_{yo}, and $\int B_y(x=0,y=0)dz$ as a function of current, as well as some values of $\int B_y(x,y)dz$ and $\int B_x(x,y)dz$ generally in 1/2 in. steps. (Note that the coordinate system used here has the x-axis horizontal, the y-axis

vertically upwards, the z-axis along the length of the magnet and the origin in the centre of the gap.) In use the three magnets were connected in series and run at a nominal current of 1400 A. Central field values were measured in situ using NMR and the results are given in Table I. Also shown in Table I are the effective lengths determined from

$$L=(\int B_y(x=0,y=0)dz)/B_{yo}.$$

For the EPB dipoles only the measurements of TM-434 were used. The R1 septum required the use of the central field value given in Table I.

TABLE I

Effective lengths and central fields at 1400 A

Magnet	L(in.)	B_{yo}(kG)
R1	158.3	16.21
EPB(I&II)	120.1	13.76

It was then assumed that the effective length was independent of the transverse position in the magnet gap. This is an excellent assumption for both magnets as the gap heights are considerably less than the lengths of the magnets. Thus the problem is reduced to determining the field components B_x and B_y (since $B_z=0$) as functions of the transverse coordinates x and y for magnets which are assumed

to be infinitely long. To do this the two-dimensional magnetostatic code, LINDA, was employed. Field maps were generated subject to the condition that the central field value, B_{yo}, be the same as that given in Table I. The calculated values of $B_y(x,y)$ and $B_x(x,y)$ were assumed to be valid for all $|z|<L/2$. Resulting values of the integrals

$$\int B_y(x,y)dz = B_y(x,y)L \propto B_y(x,y)$$

and

$$\int B_x(x,y)dz = B_x(x,y)L \propto B_x(x,y)$$

were compared with measured values whenever possible to verify the validity of the procedure.

Results

For the EPB dipoles the calculation was done using 1/16 in. for the horizontal and vertical mesh intervals. LINDA required a current of 1430 A which is in good agreement with the nominal value of 1400 A and indicates that the magnet iron was slightly different from that assumed for the calculation. As this magnet is a symmetric-H type, only one quadrant of field was required. The calculated values of B_y at y=0 and y=3/8 in., and of B_x at y=3/8 in. are plotted in Figures 2, 3 and 4 respectively. The curves are the results of the LINDA calculation and the points are average measured values from TM-434 obtained by multiplying relative $\int Bdz$ values by 13.76 kG. The agreement is excellent, any discrepancy easily being accounted for by

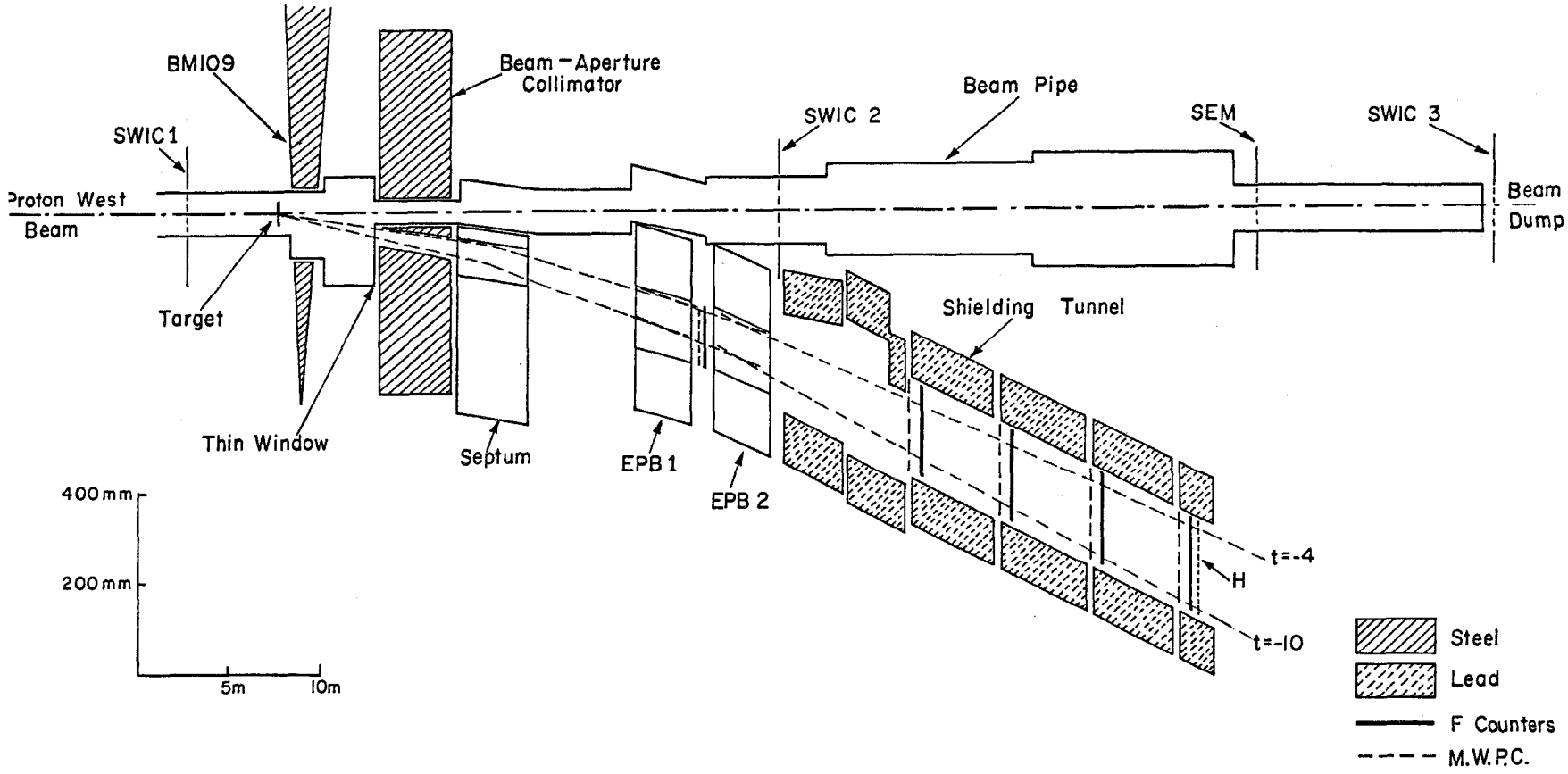
uncertainty in the position of the long flip coil used for the $\int Bdz$ measurements.

For the R1 septum a mesh interval of 1/8 in. was used. The calculation was done assuming the magnet to be a C-magnet with the positive direction of x towards the open or septum side. This is satisfactory since the septum is very thin and is 1/2 in. away from the edge of the pole tip. The calculation required a current of 1360 A to produce a central field of 16.21 kG, again consistent with uncertainties in the properties of the magnet iron. Figure 5 shows the values of B_y as a function of x for y=0 and y=0.3 in., and as a function of y for x=0 and x=+2.7 in. The curves are the results of the calculation and the points are measured values from TM-450. These authors had some problem with their coordinate system and to obtain agreement we have had to shift their negative x points by 5/32 in. but not their positive x values. Otherwise agreement is consistent with their measurement accuracy.

Ray Tracing

Punched card decks have been produced which give B_x and B_y as functions of x and y for both types of magnet. Intermediate values are obtained by linear interpolation in the respective grids. The resulting relative field values should also be good for current variations of approximately $\pm$20% from the nominal 1400 A provided that the correct overall normalization is used. Note that the x-component of field will generate significant vertical focussing or defocussing and requires that full three-dimensional tracking be used. In Figure 6 we show the result of tracking the scattered proton from p-p elastic events in the horizontal plane as a function of |t| for an

incident momentum of 300 GeV/c. This was done for a nominal spectrometer current of 1150 A which required that the fields be scaled by factors of 0.86737 and 0.86991 for the R1 septum and EPB dipoles respectively. The solid curve shows the extension of the usable range of |t| produced by allowing for the transverse field profiles.



Experiment 177 Forward Spectrometer

FIGURE 1

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EPB Dipole

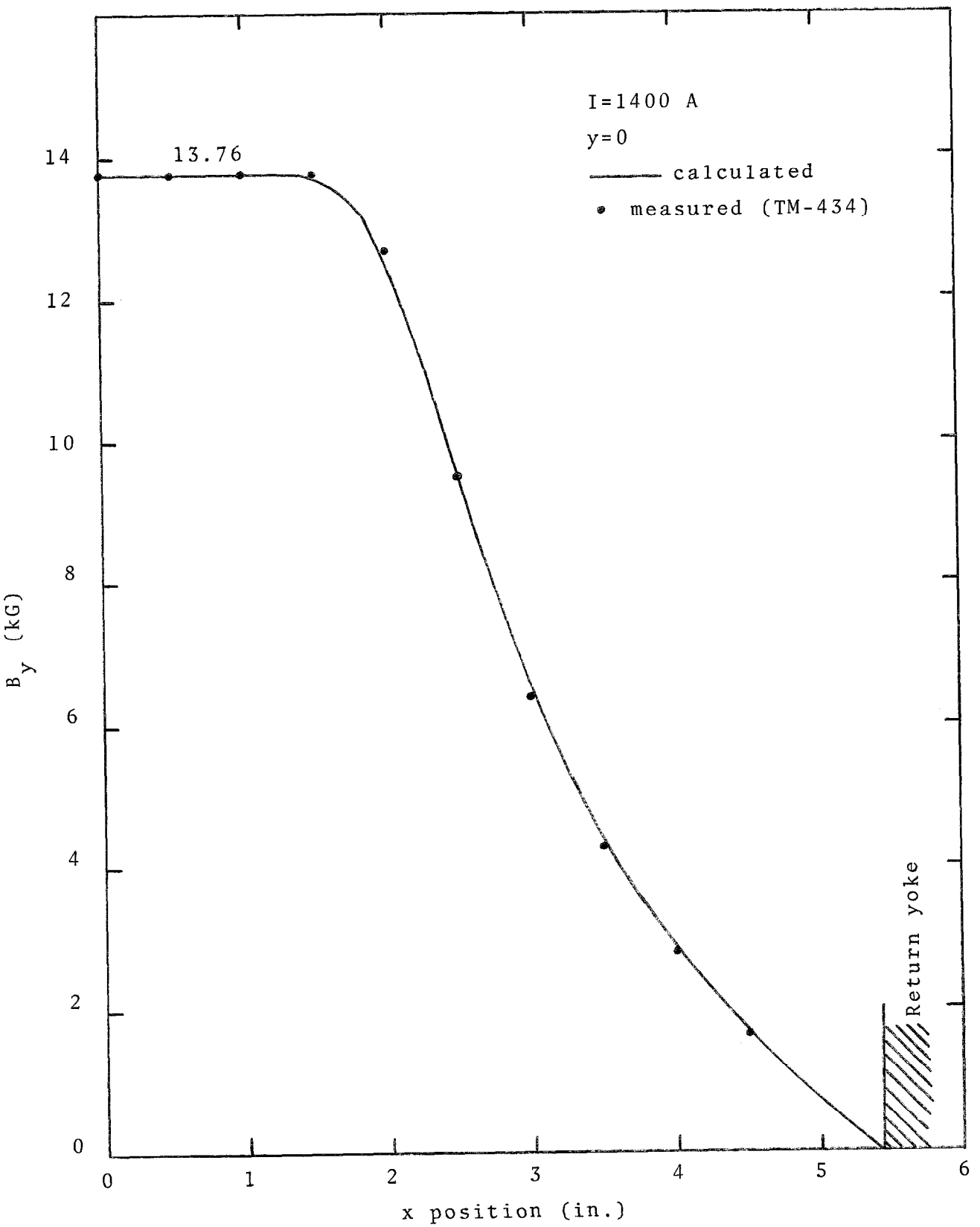

FIGURE 2

EPB Dipole

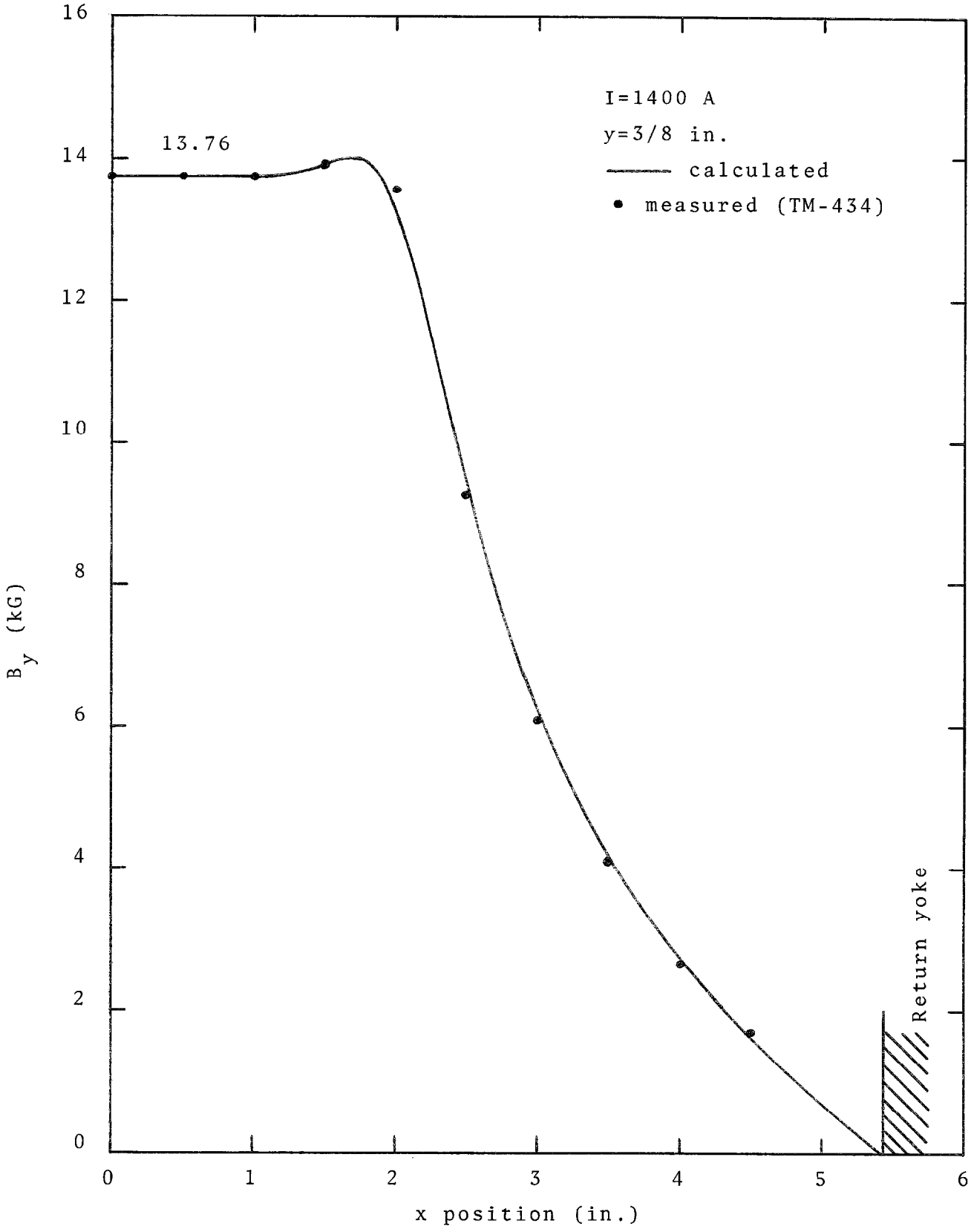

FIGURE 3

EPB Dipole

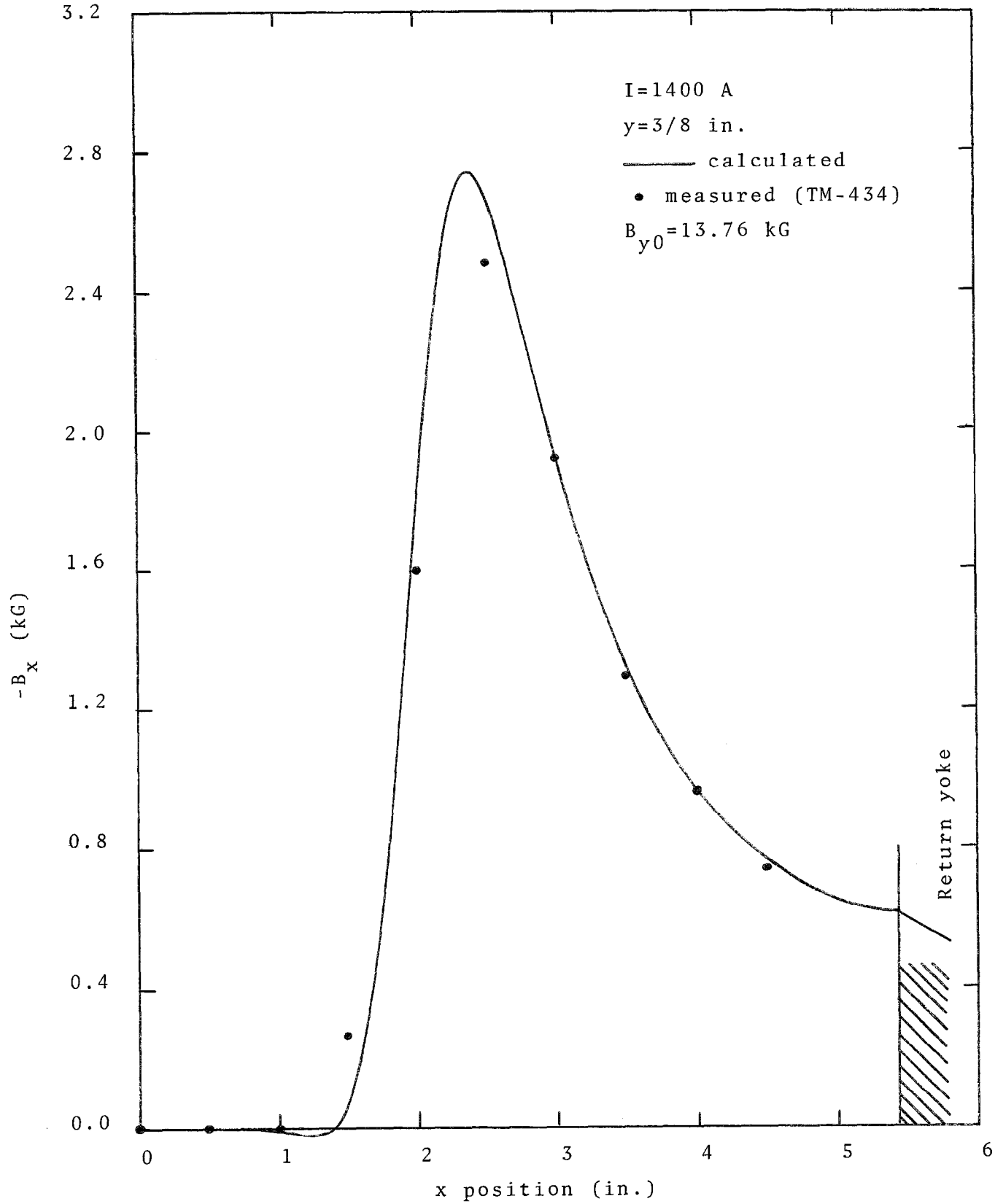

FIGURE 4

R1 Septum (I=1400 A)

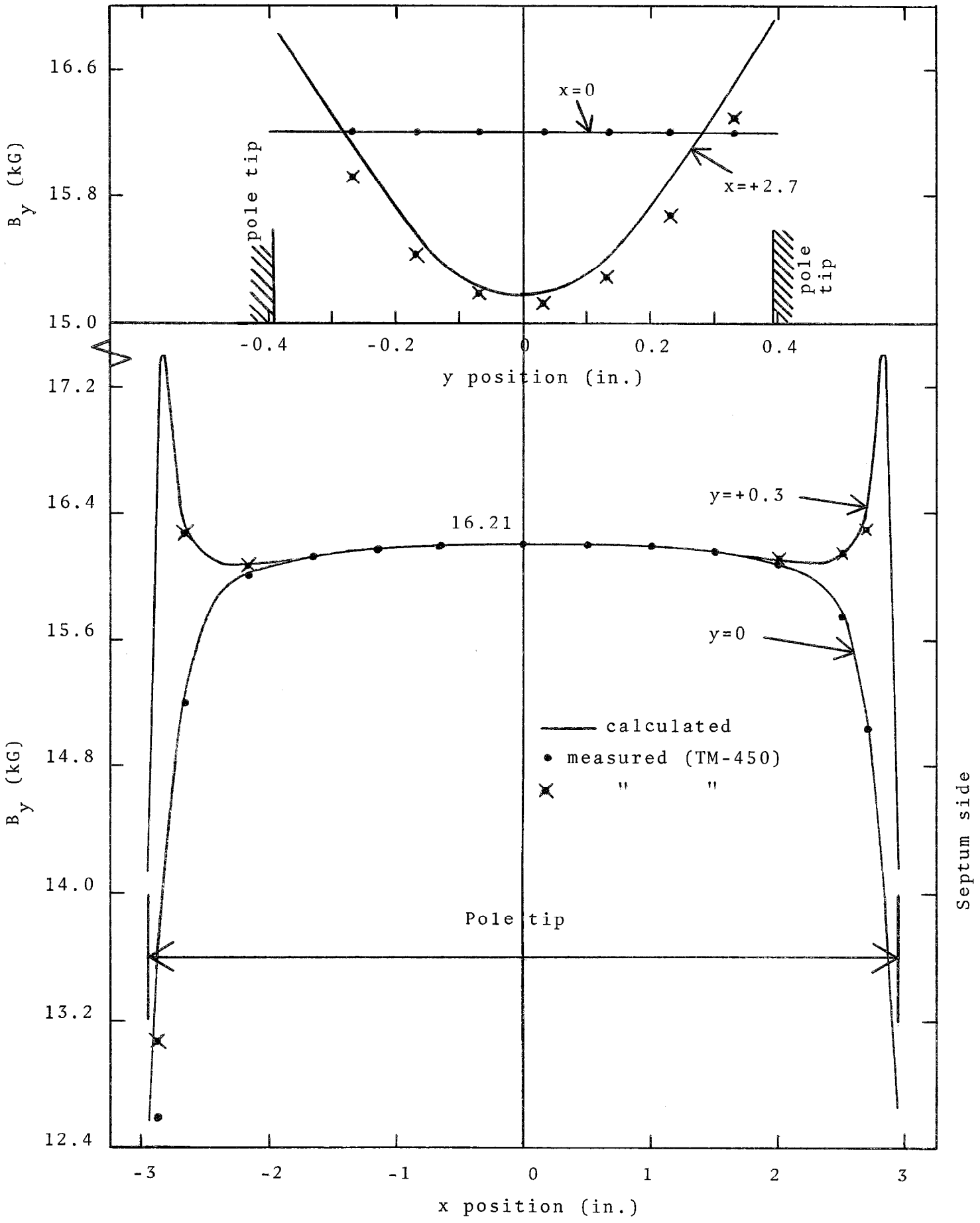

FIGURE 5

E-177 Forward Spectrometer

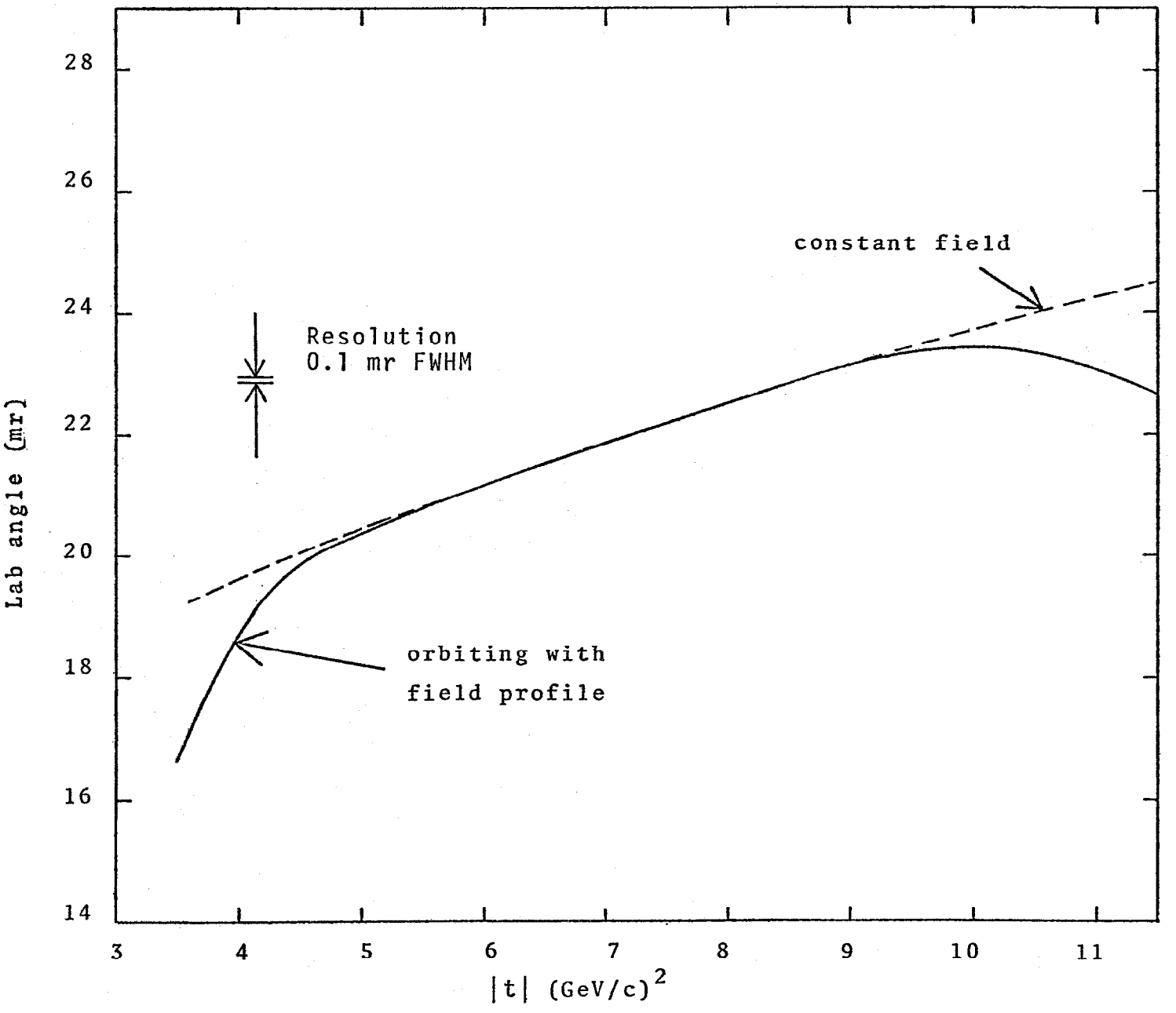

FIGURE 6